Chapter 10
LID Design Practices and Techniques

IMPORTANT

ME DEP strongly encourages the use of LID measures. LID helps reduce stormwater impacts by minimizing developed and impervious areas on a site and through the incorporation of runoff storage measures dispersed throughout a site.

Description

Low impact development (LID) is a process of developing land to mimic the natural hydrologic regime. It incorporates land planning and design practices and technologies to achieve this objective. LID begins at the design phase of a new development, incorporating planning techniques to minimize site clearing and impervious surfaces. This first step helps to reduce stormwater runoff generated from the site. By reducing the volume of water leaving a site, the pollutant loading is also reduced - less runoff equals fewer pollutants. Other low impact development techniques are then incorporated into the design and used throughout the site to keep the runoff that is generated from the site on the site. When incorporated and designed properly, LID reduces both the volume and peak flow rates of runoff generated from a development. LID is an effective tool to protect stream flows, minimize stream channel erosion, reduce pollutant loadings and reduce thermal impacts.

The use of LID practices has benefits to the developer, the municipality in which it is being used, and the environment. These include:

Chapter Contents:

Benefits to the Developer

- Reduces land clearing and grading costs
- Reduces infrastructure costs
- Reduces stormwater control costs
- Increased house lot value - more income

Benefits to the Municipality

- Protects open space
- Protects drinking water quantity
- Keeps drinking water pure
- Promotes water conservation
- Reduces maintenance costs associated with infrastructure

Benefits to the Environment

- Preserves the hydrologic cycle
- Protects streamflows
- Fish and wildlife benefits
- Reduces flooding and property damage from peak flows
- Protects streambanks from erosion

Site Suitability Criteria

LID is a concept that can be incorporated into any site development. It is not a rigid set of standards or a one size fits all approach. It is up to the design engineer to develop creative ways to prevent, retain, detain, use and treat runoff with features unique to that site. The planning components of LID can fit any site with any soil type. The key is to creatively design a site that minimizes site disturbance and the total amount of impervious surface created. The structural techniques generally involve infiltration, but can be adapted for retention by including underdrain filters for tight soils. The design criteria for infiltration and underdrain filters should be followed in these cases.

10.1 Planning for LID

Planning is the first step in incorporating LID into a new development. The developer should plan on investing more time and money in the initial planning phase, which can later be recouped through the reduced infrastructure and higher house lot sales. LID goals and objectives should be incorporated into the site planning process as early as possible. When incorporated at the early stages, LID site planning can allow for full development of the property, while maintaining natural hydrologic functions. The following steps serve as a guideline to use in the planning stage. Refer to the selected references for more information on planning and designing for LID.

IMPORTANT
Design Tips

It is critical to incorporate LID measures in the planning phase of a development. This will help to minimize stormwater runoff, which can reduce the size and cost of structural measures needed for ultimate treatment. The following planning components should be considered:

- Minimize site clearing
- Minimize impervious areas
- Minimize connected impervious areas
- Maintain time of concentration
- Manage stormwater at the site

1. Identify and preserve sensitive areas that affect the hydrology. Features that should be protected include floodplains, streams, wetlands, buffers, woodland conservation zones, steep slopes, and high-permeability soils.
2. Layout alternative development schemes to minimize site disturbance and impervious

area, while achieving full development of the site. This should incorporate the minimization of site clearing.

3. Once a layout is selected, minimize the impervious surfaces directly connected to drainage conveyance systems.

4. Incorporate LID techniques to control stormwater at the source. Think small and break the site into several smaller drainage areas that can be handled through simplistic LID practices.

Some of these key planning features are discussed further below.

10.1.1 Minimize Site Clearing

Development typically involves the creation of impervious surfaces such as roads and buildings, as well as disturbed pervious areas such as lawns and landscaped areas. Removal of topsoil and trees results in increased runoff, higher potential for erosion, decreased infiltration capacities, and decreased habitat. Removal of trees and topsoil also degrades the quality of the planting environment, resulting in landscapes that require high water usage and the application of fertilizers and pesticides, which results in greater environmental impacts and higher costs to the homeowner. Minimizing site clearing and directing development to areas that are less sensitive to disturbance reduces runoff and promotes groundwater recharge. For example, developing on lightly vegetated, tight clay soils will have less impact on stormwater runoff than clearing and developing on forested, sandy soils. Sensitive areas initially identified in the planning phase should not be developed.

The following standards should be followed to minimize site clearing.

- Identify and clearly show sensitive areas (i.e., floodplains, streams, wetlands, buffers, woodland conservation zones, steep slopes, and high-permeability soils), clearing and grading limit lines, stockpile areas, and proposed development when planning a new development. These should be included on the plans submitted for review and approval, along with the existing vegetation to be preserved.

- Place areas of development outside of sensitive areas.

- Avoid developing high-permeable soils.

- The amount of topsoil left for lawn and landscaped areas and any other disturbed pervious areas should follow the landscape design standards in Appendix B in Volume I. If topsoil is to be exported from the site, the cubic yards removed and the remaining depth of soil left for lawn/landscaped areas shall be noted for approval by the Department. The percent organic content of topsoil remaining in lawn areas should also be noted.

- Prior to commencement of construction activity, clearing and grading limit lines shall be staked in the field and checked by the Department.

10.1.2 Minimize Impervious Areas

Once the sensitive areas have been identified, the road and lot layouts should be developed. The traffic distribution network (roadways, sidewalks, driveways, and parking areas) is generally the greatest source of site imperviousness and these should be the focus for reducing impervious area. Impervious areas contribute significantly to the volume and rate of runoff from a development and their reduction will aid to reduce these impacts. Methods that can be used to reduce imperviousness are presented below:

- **Alternative Roadway Layout:** The layout of a subdivision and its roads contributes significantly to the amount of imperviousness. Alternative road layouts can be used to reduce total pavement, while allowing for the same number of lots. The use of cluster designs as opposed to the traditional grid design is one example of how changing road layout can considerably decrease imperviousness. This is illustrated in Figure 10-1. (grab figure 2-9 from Low-Impact Development Design Strategies, An integrated Design Approach, June 1999)

- **Narrow Road Sections:** Roadways often include paving of the primary driving surface as well as the shoulder and in many cases include a curb and gutter layout. The width of pavement can be reduced to include the primary driving surface only, providing pervious pavers for the shoulder and ditch drainage swale in place of the curb and gutter. This will reduce the total amount of site imperviousness, as well as minimize clearing and grading impacts, which results in lower construction costs. However, cities and towns must allow for the narrower roads in order for this option to be used.

- **Reduced Application of Sidewalks to One Side of Primary Roads:** Paved sidewalks add a significant amount of impervious area to a development. Where necessary, sidewalks should be reduced to one side of the road only. In other areas, such as on smaller secondary roads, sidewalks may be eliminated altogether.

- **Reduced On-Street Parking:** On street parking significantly increases the width of a road, and therefore total site imperviousness. Reduction to one side or elimination of on-street parking can potentially reduce overall site imperviousness by 25 to 30 percent (Sykes, 1989).

- **Rooftops:** Rooftops are also a source of imperviousness. The number and size of buildings will dictate the impervious area associated with rooftops. For example, larger one-story homes will result in more impervious surface than the same size homes built with two stories. Vertical construction is preferred over horizontal construction for this reason. In addition to reduction in total roof area, greenroofs are another option to reduce impervious surfaces. Greenroofs act to reduce the amount of runoff generated from the rooftop.

- **Driveways:** Minimizing paved driveway area can also reduce imperviousness. This can be accomplished through narrower driveways (maximum 9 feet wide) or minimizing setbacks from road to reduce length. The use of shared driveways will also help to reduce imperviousness. In addition to these options for reducing the size of the driveway, alternative materials may be used such as porous pavers or gravel to minimize the runoff from driveways. Alternative materials are discussed in more detail in section 10.2.6.

10.1.3 Minimize Connected Impervious Areas

No matter how much pre-planning is performed, there will be some impervious surfaces that will generate runoff. The impacts from these impervious surfaces can be minimized by disconnecting these areas from piped drainage networks and instead treating these at the sources. For example:

- Roof drains should be directed to vegetated areas rather than impervious surfaces and piped drainage networks.

- Paved driveways and roads should be directed to stabilized vegetated areas.

- Flows from large paved surfaces should be broken up and for on-site treatment of smaller flows. Breaking flows up allows the flows to be directed to vegetation as sheet flow.

- LID techniques should be used to treat flows from impervious surfaces. These should be dispersed throughout the development, such as at individual house lots to obtain the most benefit. They can be incorporated into the landscaping of the property to provide a natural treatment system.

10.1.4 Maintain Time of Concentration

Time of concentration (Tc) is the time it takes for stormwater runoff to flow from the furthest point in the watershed to the point of interest. It is based on the flow path and length, ground cover, slope and channel shape. When development occurs, the Tc is often shortened due to the impervious area, causing greater flows to occur over a shorter period of time. LID practices can be used to help maintain the pre-development Tc. These include:

- Increasing the flow length
- Increasing the surface roughness of the flow path
- Detaining flows on site
- Minimizing land disturbance
- Creating flatter slopes
- Disconnecting impervious areas, which will decrease their travel rates

10.1.5 Manage Stormwater at the Source

Once the development has been designed and the LID practices above have been incorporated, the remainder runoff from the site can be handled through various LID techniques, which are discussed further below. The key is to try to mimic natural hydrologic functions and the best way to do this is to mitigate impacts at the source. This allows for more even distribution of flows, rather than trying to control it at the end of the pipe. For example, using drywells to infiltrate roof runoff is a great method to prevent more street runoff that will become contaminated and add to the volume requiring treatment. It also helps in reestablishing a more natural hydrologic cycle.

Smaller treatment sites such as rain gardens and swales that only handle a small area use the soil matrix for treatment and are quite effective. These smaller sites have not been found to create groundwater pollution but instead the microorganisms in the soil rapidly break down pollutants and produce clean groundwater. Since so many areas have declining groundwater due to imperviousness (by prevention of recharge), this can help reestablish the natural hydrologic cycle and produce clean baseflow for stream discharge. The designs in Section 10.2 of this chapter give guidance on structural techniques that can be used to minimize runoff from development in northern climates. Using a combination of alternative designs will result in a more effective stormwater management design and may also provide more flexibility in site design by allowing a wider variety for locations of devices.

The cost benefits of this approach can be substantial. Typically, the most economical and simplistic stormwater management strategies are achieved by controlling runoff at the source.

Selected References

Comprehensive Environmental Inc. November 2003. *Design Guidelines and Criteria for Stormwater Management*. Milford, MA.

Prince George's County. June 1999. *Low-Impact Development Design Strategies: An Integrated Design Approach*. Largo, MD.

Sykes, R.D. 1989. Chapter 3.1 - Site Planning. University of Minnesota.

10.2 LID Techniques

Many of the LID techniques presented in this manual rely on infiltration, retention and evapotranspiration to minimize stormwater runoff. There are many sites in Maine where infiltration may not be a possibility. In these cases, the initial planning techniques described above should be the primary focus, followed by underdrained techniques that rely on soils and vegetation to retain and transpire stormwater runoff. When infiltration and/or underdrain filters are combined with the following LID techniques, the design criteria provided in respective Chapters 6.0 and 7.0 must also be followed.

10.2.1 Bioretention Areas and Raingardens

Bioretention areas or raingardens consist of a specific soil filter media, usually containing some percentage of organic material, planted with vegetation that can handle wet and dry conditions. These systems are built with a slight depression to allow shallow ponding of stormwater runoff as it infiltrates through the soil media and into the groundwater or an underdrained filter. The soil media and vegetation help reduce the volume of runoff through absorption and evapotranspiration. They are best used to treat small areas of runoff. Refer to Chapter 7.0 for further information on the performance and design of bioretention practices.

10.2.2 Infiltration

Infiltration involves the discharge of stormwater to the ground. It reduces the total runoff from a site and removes pollutants by filtration through the soils. Infiltration serves to mimic the natural hydrologic cycle by directing water into the ground, where it normally goes before development takes place. It is best to use smaller, dispersed infiltration techniques throughout a site to most effectively mimic the natural hydrologic cycle and to best fit it into the natural landscape. The most common forms of infiltration are infiltration basins, trenches and drywells, but with a little creativity, it can be incorporated into multiple forms of attractive BMPs that can be used in parking areas and landscaped settings. Refer to Chapter 6.0 for further information on the performance and design of infiltration practices. The design information in Chapter 6.0 should be followed for any infiltration practice.

10.2.3 Filter Strips/Vegetated Buffers

Vegetated filter or buffer strips use soils and vegetation to remove pollutants from storm water. Filter strips are typically used as pretreatment devices for bioretention cells and other infiltration practices, as the vegetation promotes sediment deposition from sheetflow. Buffers can be used as a stormwater BMP for small scale developments functioning to remove sediments and other pollutants and minimizing the amount of runoff generated. Refer to Chapter 5.0 for detailed information on the performance and design of vegetated buffers.

10.2.4 Vegetated Swales

Vegetated swales are typically used to convey flows to areas for treatment. They can replace conventional curb and gutter and piped systems, slowing stormwater velocities and increasing the time of concentration of flows, which in turn reduces peak flows. They also help to filter pollutants such as sediment from stormwater, and can be used as pretreatment to the ultimate treatment system. Refer to Chapter 8.0 for further information on the performance and design of vegetated swales.

10.2.5 Level Spreader

Level spreaders are typically used to convert concentrated flows into overland sheet flow. This allows for even distribution of runoff over land to minimize erosion that would normally occur with channelized flow. Refer to Chapter 8.0 for further information on the performance and design of level spreaders.

10.2.6 Porous Pavement

Porous pavement consists of the use of a permeable surface, base, and subbase materials which allow penetration of runoff through the surface and into the underlying soils. Pavement alternatives vary in load bearing capacities but are generally appropriate for low traffic areas such as sidewalks, parking lots, overflow parking and residential roads. It is important to choose a material appropriate for the desired use (light, moderate or heavy use). Maintenance is essential for long term use and effectiveness.

Porous pavement is essentially a means of infiltration, thus, pollutant removal will be similar to other infiltration practices. The efficiency of pavement alternative systems will depend on whether the pavement is designed to store and infiltrate most runoff, or only limited volumes of runoff (e.g., "first-flush") with the remainder discharged to a storm drainage system or overland flow. The effectiveness of pavement alternatives will also depend on the long term serviceability. Pretreatment of any off-site runoff that may be directed to the system is required to prevent clogging of the pavement structure and underlying soils.

This manual describes three different permeable pavement alternatives, each of which is appropriate for specific situations. These types include:

- Porous asphalt
- Block pavers
- Plastic grid pavers

Examples of these porous pavement alternatives are shown in Figure 10-2.

Types of Porous Pavement

A typical permeable pavement alternative consists of a top porous asphalt, block paver or plastic grid paver course, a filter course, a reservoir course, a geotextile filter fabric and existing soil or subbase material. Brief descriptions of three types of porous pavements are provided below. A comparison of the three alternatives is provided in Table 10-1, with general design and maintenance criteria provided further in this section.

Porous Asphalt

Porous asphalt is very similar to conventional asphalt except that it is mixed without particles smaller than coarse sand (less than 600 µm or No. 30 sieve). Without these smaller size particles water is able to pass through the surface and into a crushed stone storage area which allows the water to slowly infiltrate into the ground.

The lack of fine particles in the material limits the load capacity of the asphalt compared to conventional asphalt thus it should not be used for areas of high traffic. However, porous asphalt needs less stormwater conveyance systems and less other additional BMPs.

Block Pavers

Block pavers consist of a set of interlocking, normally concrete pavers that connect in a way to leave open or void spaces between them to allow water to infiltrate into the underlying gravel reservoir. Typical installation consists of a soil subgrade, a gravel subbase, a layer of bedding sand, and the grid pavers. The infiltration capacity is based on the thickness of the gravel subbase and the material in the void space. Void spaces can be filled with gravel or soil and grass.

Plastic Grid Pavers

Plastic grid pavers are often constructed from recycled material. They generally come in a honeycomb pattern and the voids are filled with either gravel or soil and grass depending on use. The grid pavers give added stability to and allow minimal compacting of soils in voids. They are flexible and can be used in areas with uneven terrain.

Table 10-1
Comparison of Porous Pavement

	Porous Asphalt	Block Pavers	Plastic Grid Pavers
Application	•Parking areas •Pedestrian walkways •Overflow & event parking •Roadways with light traffic •Tennis and basketball courts •Bike paths	•Parking areas •Pedestrian walkways •Overflow & event parking •Roadways with light traffic •Driveways •Medians •Fire lanes	•Parking areas •Pedestrian walkways •Driveways •Fire lanes •Emergency access roads •Golf cart paths •Bike paths
Design Strength	Slightly less than porous concrete, which is between 259,200 and 345,600 lbs/ft^2	About 1,150,000 lbs/ft^2	24,000-820,000 lbs/ft^2 depending on the type chosen
Life Span (assuming proper maintenance)	15-20 years	Most have lifetime guarantee	Varies by manufacturer
Subbase	Geotextile fabric topped with 18-36" of washed crushed stoned topped with 1" of chocker course	Geotextile fabric topped with minimum 6" of gravel topped with 1" sand bedding layer. Residential use can omit gravel base. Fill voids with gravel or soil and grass.	Varies depending on manufacturer. Some grids lay directly on existing grass. Others require gravel subbase or planting base. Voids typically filled with gravel or soil and grass.
Maintenance	•Annual inspection for deterioration •Periodic vacuum sweeping •Fill small potholes and cracks with patching mix unless >10% of surface •Drill 0.5" holes every few feet to address spot clogging •No sanding •No salt near groundwater drinking supplies •Raise plow blade 1" above surface	•Refill voids •Replace damaged blocks •Mow, water and seed grass as needed •Use salt and sand sparingly •No salt near groundwater drinking supplies •Plowing allowed	•Refill voids •Replace damaged sections as needed •Mow, water and seed grass as needed •Use salt and sand sparingly •No salt near groundwater drinking supplies •Raise plow blade slightly or outfit with flexible rubber bottom piece

Adapted from University of Rhode Island Cooperative Extension. 2005

General Site Suitability Criteria

- **Soils:** Soils with field-verified permeability rates less than 0.50 inches per hour or with a clay content greater than 30%, are not suitable for pavement alternatives. Soil borings must be taken two to four feet below the level of the base of the pavement system or the bottom filter course, whichever is deeper, to identify any restrictive layers (Schueler et al., 1992)

  - o Frost-susceptible soils are not good candidates for pavement alternatives.

  - o Pavement alternatives should not be used on an unstable subgrade of fill soils (especially when wet), or if prone to slope failure. (Sites without suitable natural soils for infiltration may possibly be used for pavement alternatives, but would require extensive excavation and replacement with suitable sub-base material and provision of subsurface drainage, with an outlet to discharge the partially treated percolate from the system).

- **Traffic Volumes:** Pavement alternatives are limited to areas with light to moderate traffic. They are not generally recommended for most roadways, and cannot withstand use by heavy trucks (Schueler et al., 1992). Typically, they are used for lightly used satellite or seasonal parking areas and access drives.

General Design Criteria

- **Site Slope:** The slope of the site should be less than 5% (Schueler et al., 1992b) and preferably closer to 1%.

- **Separation from Seasonal High Water Table & Bedrock:** Three feet of minimum clearance is required between the bottom of the system and bedrock or seasonal high water table, whichever is shallower (Ibid.)

- **Sediment Loading:** Pavement alternatives should not be used in areas expected to receive high levels of sediment loading from upland areas. Also, if used during the winter, these areas should not be sanded. The pavement surface and sub-structure are highly susceptible to clogging, and should be protected against sediment input.

- **Subgrade/Natural Soils:** The subgrade soils shall have a field-verified permeability of at least 0.50 inches per hour (Schueler et al., 1992)

- **Porous Asphalt Course:** The top porous asphalt course should be 2-4 inches thick, depending on load and traffic application. A typical porous asphalt mix is provided below. The porous asphalt mix and thickness shall be designed based on site specific conditions such as the use of the paved area, the required load bearing capacity, climate, etc.

Typical Porous Asphalt Gradation

Sieve Size	Percent Passing
1/2”	100
3/8”	95
#4	35
#8	15
#16	10
#30	2
Percent bituminous 5.75-6.0% by weight	

Adams, 2003

- **Filter Course:** A filter course shall be provided between the top porous asphalt or paver course and the reservoir course. This provides a level surface to construct the top porous asphalt or paver course. The filter course is typically a 1 to 2 inch thick layer and should meet the following gradation requirements:

Typical Filter Course Gradation	
Sieve Size	**Percent Passing**
1/2”	100
3/8”	0-5

- **Reservoir Course:** The reservoir course shall be clean, washed, 1½ -inch to 3-inch aggregate, free of debris. The depth of the reservoir course shall be based on the desired storage volume and frost penetration. Stone gradation should meet the following:

Typical Reservoir Course Gradation	
Sieve Size	**Percent Passing**
2 1/2”	100
2”	90-100
1 1/2”	35-70
1”	0-15
1/2”	0-5
#30	2

- **Geotextile Fabric:** A geotextile fabric with suitable characteristics must be placed between any stone layer and adjacent soil. The fabric will prevent the surrounding soil from migrating into the system and reducing its storage capacity. Use an appropriate geotextile design manual to choose a fabric that is compatible with the surrounding soil for the purposes stated above. The filter fabric should be free of tears, punctures, and other damage. Overlap seams a minimum of 12 inches.

- **Cold Climates:** Demonstration projects have shown successful applications of pavement alternatives in regions with freeze/thaw conditions, such as in Rochester, NY (Field, 1982), Philadelphia (Glourek and Urban, 1980), and Concord, MA. However, winter maintenance procedures may be problematic (e.g., scraping by plows, clogging by sand, clogging by or inability to treat de-icing chemicals). The University of Rhode Island and the University of New Hampshire are currently in the process of testing various porous pavement alternatives in winter climates.

General Maintenance Criteria

- **Inspection Frequency:** Inspection several times during the first few months following construction, followed by annual inspections. Inspections should be made after significant storm events to check for surface ponding that could indicate failure due to clogging.

- **Snow Removal:** Snow removal and deicing activities should be done carefully to avoid disturbance to the pavement structure and stripping of any vegetation. The plow blade should be raised 1" above the surface or outfitted with a flexible rubber bottom piece.

- **Rehabilitation:** Non-routine maintenance may require reconstruction of the surface treatment, and possibly the filter and reservoir layers, to relieve major clogging. Measures should be taken to ensure that an area designed to be porous does not receive a future overlay of conventional non-porous paving.

Selected References

Adams, Michele. (2003). “Porous Asphalt Pavement with Recharge Beds: 20 Years & Still Working.” *Stormwater*, May/June 2003. Retrieved November 10, 2005 from the World Wide Web http://www.forester.net/sw_0305_porous.html

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Maryland Department of the Environment. 1984. *Maryland Standards and Specifications for Stormwater Management Infiltration Practices.* State of Maryland Department of the Environment, Sediment and Stormwater Administration. Annapolis, MD.

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Thelen, E. and L.F. Howe, Jr. 1978. *Porous Pavement.* The Franklin Institute Press, Philadelphia, PA.

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An introduction to permeable pavement alternatives" Kingston, RI.

10.2.7 Rain Barrels and Cisterns

Rain barrels are inexpensive, effective, and easily maintainable devices that are designed to capture roof runoff. They are most commonly used in residential applications to capture roof runoff for later watering of lawns and gardens. Rain barrels include a hole at the top to allow for flow from a downspout, a sealed lid, an overflow pipe and a spigot at or near the bottom of the barrel. A screen is often included to control mosquitoes and other insects. Rain barrels can be connected in series to provide larger storage volumes.

Cisterns are distinguishable from rain barrels only by their larger sizes and different shapes. They can be located either above or below ground, and in out of the way places that can easily be incorporated into a site design. Commercially available systems are typically constructed of high-density plastics and can include pumps and filtration devices. Cisterns can have up to a 10,000 gallon capacity.

Design Criteria

- **Sizing:** The required capacity of a rain barrel or cistern is a function of the rooftop surface area that drains to it, the inches of rainfall required to fill the barrel, and water losses, due mainly to evaporation. A general rule of thumb to utilize in the sizing of rain barrels is that 1 inch of rainfall on a 1000 square foot roof will yield approximately 600 gallons. Actual barrel is recommended to be at least 55 gallons.

- **Cistern Sizing Addendum:** Cisterns designed for more than just supplemental use (i.e., for full time domestic use) should be sized based upon a minimum of 30 gallons per day per person when considering all potential domestic water uses

- **Covers and Screens:** Provide removable, child-resistant covers and mosquito screening on water entry holes.

- **Drain Spigot:** Equip rain barrel with drain spigot with garden hose threading.

- **Safety:** Consider a sealed yet removable child resistant top.

- **Material:** Rain barrels are traditionally made of plastic. Cisterns can be mad out of redwood, polyethylene, fiberglass, metal, concrete, plaster (on walls), ferro-cement and impervious rock such as slate and granite.

Maintenance Criteria

- Maintenance requirements for rain barrels and cisterns involve inspection at least twice a year and the repairing or replacement of appropriate components. Inspections and repairs should be done during dry parts of the year such as in summer but it is helpful to have the option of completely draining the system for maintenance.

- **General Inspections:**
  - Roof catchments, to ensure that no particulate matter or other parts of the roof are entering the gutter and downspout to the rain barrel.
  - Gutters and downspouts, to ensure that no leaks or obstructions are occurring.

- **Rain barrel Inspections:**
  - Rain barrel, to check for potential leaks, including barrel top and seal.
  - Runoff /overflow pipe, to check that overflow is draining in non-erosive manner.
  - Spigot, to ensure that it is functioning correctly.

- **Cistern Inspections:**
  - Roof washer and cleanout plug, inspection and replacement if needed.
  - Cistern screen, cover and overflow pipe, inspection and replacement if needed.

Selected References

Low Impact Development Center. http://www.lid-stormwater.net/raincist/raincist_home.htm

10.2.8 Rooftop Greening

Rooftop greenery involves the establishment of vegetation on the rooftops of both new and existing buildings. This is a long-standing practice conducted throughout Europe. It provides three primary benefits: attenuation of stormwater runoff and peak flows, reductions in the heat island effects with significant improvements in building insulation, and the substantial increase in the life expectancy of the base roof material. The obvious stormwater benefit is that green roofs act to absorb the smaller, more common storm events, minimizing peak runoff and the net volume of stormwater runoff typically produced by roofs. Green roofs are not specifically intended to reduce atmospheric pollutant loadings because of the relative porous nature of the growth media.

In the world of green roofs, there are two primary types: extensive and intensive. The term "extensive" simply represents the practice of covering the entire roof area in a vegetative mat. These systems are designed to provide only a few inches of growth media and are relatively lightweight in structure. Because of the focus of minimizing weight/growing media, the vegetation is typically limited to various species of sedums or other similar arid plants. Due to the shallow media, the roofs have little organic substrate to retain potential pollutant loads.

The term "intensive" represents additions to the roof intended for general access and reuse of the rooftop resembling that of open space such as parkland, where direct access and use by the building inhabitants is encouraged. Intensive roof landscaping runs the gamut from small city parks to commercial enterprises representing sidewalk cafes, etc. This type of green roof typically requires more growth media and significant additional weight loading to the roof structure which would need to be accounted for. The deeper media provide for more nutrient uptake and greater flow attenuation.

One point of consideration is that data for thin media green roofs has shown that the runoff water quality can be impacted by the organic media it flows through. As such, the initial flow from rainwater will typically contain elevated levels of organic constituents such as nitrogen and phosphorus, depending on the growth media used, including the depth and the absorptive capacity of the media. To address this issue, typical green roof designs include residual stormwater detention tanks with a pump back system. The recirculating system allows for watering of the media during dry periods, providing for additional uptake of first flush pollutants and summertime evaporative cooling and reduction in the heat island effect experienced in most cities.

Design and Construction Criteria

Green roofs represent a technology onto themselves for which numerous technical and reference manuals are available. In summary, typical green roofs include the planting media underlying highly permeable growth media, a protective geotextile liner, and a root barrier membrane that consists of an impermeable membrane consistent with typical roof construction practices within the region. As stated, the inclusion of a containment structure for the first flush significantly improves stormwater water quality and enhances the overall effectiveness of the green roof technology. Planning and designing for a green roof requires that all characteristics of the building related to structural and vegetation-technical aspects be evaluated. The following design criteria are provided as guidelines. A structural engineer should be consulted to ensure the building can support the added weight from the planting media and vegetation.

1. **Suitability for Use:**. Access to vegetated areas should be restricted to people who care for and maintain the site.
2. **Roof Slope:** Roof slope has to be taken into account along with structural and vegetation requirements. A minimum slope of 2% is considered normal for extensive and simple intensive greening. In extensive greening, controlled drainage will meet the basic needs of the vegetation. Roofs with less than 2% slope will require special measures. Extensive greening on roofs with less than 2% slope require a drainage course to avoid water logging in the vegetation support course.
3. **Roof Design Suitability for Greening:** Green roof design requires consideration of a variety of conditions, involving both the way in which the site is constructed and the physical conditions on-site. The physical characteristics of roof structures must be checked.
4. **Design Loads:** The design load of the building is the critical factor in deciding what type of greening to use and how to cultivate the site. All the courses must be considered, at maximum water capacity and including the surface load generated by the vegetation, as a component in the surface load. The load generated by any water stored in an integral reservoir will also need to be added into the figures. Spot loadings generated by large-scale bushes, trees and structural components, such as pergolas, water pools and peripheral items, will need to be calculated separately.
5. **Protection Against Falls:** Protection devices preventing falls during execution, care and maintenance activities on buildings (e.g., barriers, options for securing workers with ropes) must be incorporated into design.
6. **Draining:** Drainage must be available through the layered superstructure and off the surface. Excess water may be drained within the vegetation area, outside the vegetation area, or through separate drainage facilities for areas which have undergone greening and those which have no vegetation. Regardless of the size of the roof surface, roofs with drainage facilities located

within the vegetation area must have at least one run-off facility and at least one emergency overflow.

7. **Watering:** The number of mains pipes and junction points required for watering, along with the sizes used, will depend upon local conditions and on the structure involved.

8. **Compatibility of Materials:** All materials used for the roof and vegetation layered superstructure must have mutual chemical compatibility.

9. **Environmental Compatibility:** The materials used must not be allowed to generate atmospheric pollution due to processes such as leaching or the release of gaseous substances.

10. **Plant Compatibility:** Materials must not contain any components which are harmful to plant life and which are capable, over a given period, of finding their way out into the environment.

11. **Protection Against Root Penetration:** Both intensive and extensive green-roof sites must have suitable and lasting protection against root ingress or penetration which would damage the damp-proof lining. Protection against root penetration may be provided by means of protective sheeting or full surface treatment/liquid coating. Floors made of non water-permeable concrete and welded metal vats are resistant to rood penetration. Settlement joints in floors made of non water-permeable concrete have to be equipped with a special treatment against root penetration.

12. **Protection Against Mechanical Damage:** Damp-proof linings and root-penetration barriers on roofs can be protected against mechanical damage by:

- Protective non-woven fabrics
- Protective boards
- Protective sheeting
- Full surface treatment, or
- Drainage courses

13. **Drainage Facilities:** Drainage facilities must be capable of collecting both overflow from the drainage course and surface water from the vegetation support course and of conveying it away. Water from adjoining facades has to be drained off in such a manner that the functions of the vegetation course and structure are not impeded. Materials consist of::

- Roof outlets
- Interior guttering
- Guttering
- Downpipes, and
- Emergency overflows

14. **Joints and Borders:** Joints and borders include joints with facades and other vertical structural components, joints where the roof is penetrated, and borders at roof edges. Damp-proof lining/root-penetration barriers on roofs must be brought up to the following heights:

- 15 cm high for a roof slope of up to 5°
- 10 cm high for a roof slope of over 5°

The minimum height for borders is:

- 10 cm high for a roof slope of up to 5°
- 5 cm high for a roof slope of over 5°

As a rule, a strip made up of slabs or gravel must be provided to separate vegetation areas from the structural component in question.

15. **Protection Against Emissions:** Areas affected by ventilation and/or air-conditioning should be evaluated to determine their suitability for planting, and the best types of vegetations suited to them. The generation of warm and cold air and currents can cause frost and drought damage to plants.

16. **Wind Loads:** Wind can generate positive and negative pressure forces, as well as friction, which act on structures. The strength of these forces is a direct function of wind strength and direction and of the shape and height of the building in question.

17. **Protection Against Slipping and Shearing:** Where a roof slopes at an angle in excess of 200 (36% gradient), structural anti-shear protection will normally be needed. Care must be taken to ensure that the action taken to prevent shearing does not create tension at the point of contact with the damp-proof lining and the root-penetration barrier.

18. **Vegetation Support Course:** The vegetation support course should be capable of accommodating a dense root stock, having all the requisite basic physical, chemical and biological properties needed for plant growth. The type of greening and form of cultivation will be factors in selecting a vegetation support course. Available materials include

- Soil mixtures - improved top and underlying soil
- Aggregate mixtures - mineral aggregate mixtures with high or low organic content or with an open-pore granular structure with no organic content
- Substrate boards -boards made from modified foam materials or mineral fibres
- Vegetation matting - matting with mineral/organic aggregate mixtures

The organic content of the vegetation support course should be as shown below:

Type of Greening	Substrate Density	Organic Content
Intensive Greening	≤ 0.8 > 0.8	≤ 12% by mass ≤ 6% by mas
Extensive Greening		
Multiple-Course Construction	≤ 0.8 > 0.8	≤ 8% by mass ≤ 6% by mass
Single-Course Construction	N/A	≤ 4% by mass

Reference: The Landscaping and Landscape Development Research Society E.V. - FLL

19. **Filter Course:** The filter course should be designed to prevent fine soil and substrate components from being washed out of the vegetation support course into the drainage course in a slurry. Nonwoven geotextile fabrics are typically used as filter courses.

20. **Drainage Course:** The drainage course must contain sufficient spaces to take up any excess water. The drainage course may be constructed of:

- Aggregate-type materials - gravel and fine chippings, lava and pumic, or expanded clay and slate
- Recycling aggregate-type materials - brick hardcore, slag, or foamed glass
- Drainage matting - textured nonwoven matting, studded plastic matting, fibre-type woven matting, or flock-type foam matting
- Drainage boards - boards made from foam pellets, studded rubber boards, shaped rigid plastic boards, shaped plastic foam boards
- Drainage and substrate boards - boards made from modified foam

Course materials and dimensions will depend on construction requirements and objectives for vegetation.

21. **Protective Layer:** The protective layer provides additional protection for the damp-proof lining/root penetration barrier on the roof.

22. **Roof-penetration Barrier:** The root-penetration barrier must provide constant protection for the damp-proof lining on the roof by preventing plant roots from growing into or through it.

23. **Water Retention:** Percent annual water retention on green roof sites as a function of course depth is provided in the table below.

24. **Water Storage:** Water can be stored in the individual courses as follows:

    - Storage in the vegetation support course through the use of substances which retain water for vegetation substrates or prefabricated substrate boards

    - Storage in the vegetation support course and, additionally, in the drainage course, through the use either of open-pore type aggregate materials in graded granular sizes or of prefabricated draining substrate boards

    - Storage in the vegetation support course and, additionally, in the drainage course, by allowing a water supply to build up in the aggregate over the entire area or by using pre-formed drainage boards with partial retention characteristics

    Water may be stored simultaneously in the vegetation support and drainage courses, whatever type of greening is used.

25. **Additional Watering:** Green-roof sites are designed to depend chiefly on precipitation for their water supply, this being readily available without cost. Additional watering may be provided through the use of a spray or dip type hose, hose and sprinkler, an overhead irrigation system, or automated water systems where there is a built-in reservoir. Where sprinklers, spray-type watering by a hose or drip-type water is used, the system can either be operated manually or controlled by means of a timer.

Maintenance Criteria

Green roof technologies follow the same startup and maintenance criteria as would be applied to any facility landscape feature. The more complicated and intensive the green roof, the more maintenance associated with caring for the vegetation, whereas an extensive roof planted in sedums can represent little or no maintenance other than a periodic feeding during the first year of operation.

Type of Greening	Course Depth (cm)	Form of Vegetation	% Water Retention - Annual Average
Extensive Greening	2-4	Moss-sedum greening	40
	>4-6	Sedum-moss greening	45
	>6-10	Sedum-moss-herbaceous plants	50
	>10-15	Sedum-herbaceous-grass plants	55
	>15-20	Grass-herbaceous plants	60
Intensive Greening	15-25	Lawn, shrubs, coppices	60
	>25-50	Lawn, shrubs, coppices	70
	>50	Lawn, shrubs, coppices, trees	>90

Reference: The Landscaping and Landscape Development Research Society E.V. - FLL

Selected References

Dunnet, Nigel and Kingsbury, Noel, 2004. *Planting Green Roofs and Living Walls.* Timber Press, Inc., Portland, Oregon.

Green Roofs for Healthy Cities and the Cardinal Group Inc., 2004. *Green Roof Design 101 Introductory Course.*

Guideline for the Planning, Execution and Upkeep of Green-Roof Sites. January 2002. Bonn, Germany. The Landscaping and Landscape Development Research Society E.V. - FLL.

10.2.9 Other Techniques

As previously stated, LID is about creativity. There are multiple practices that can be implemented and fit into various sites and situations. For example, infiltration can be incorporated into parking lot layouts without losing any parking spaces. Several examples are included in Appendix F. These examples generally use infiltration to treat stormwater and minimize runoff, but could easily be modified to incorporate an underdrain soil filter for tighter soils.

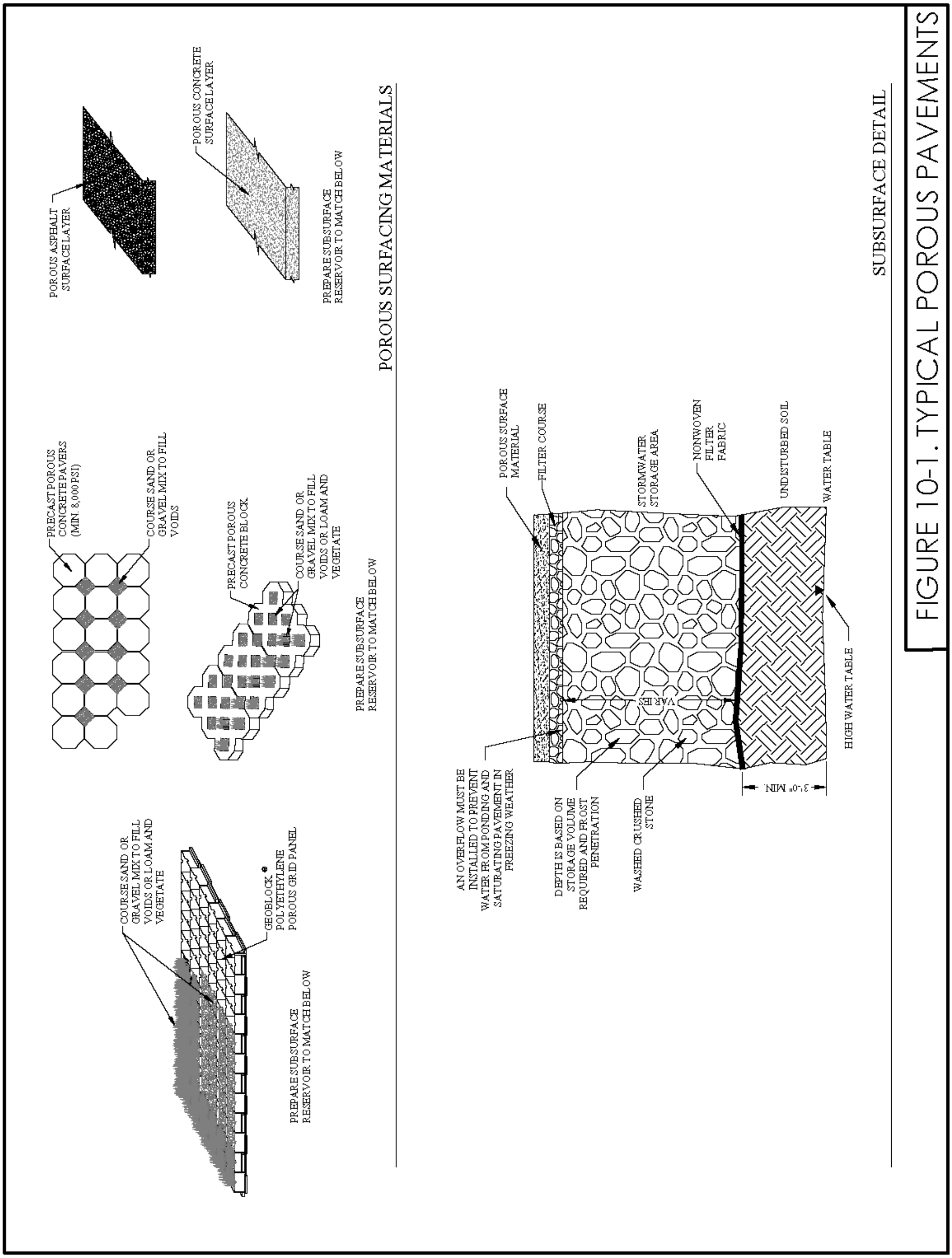

FIGURE 10-1. TYPICAL POROUS PAVEMENTS

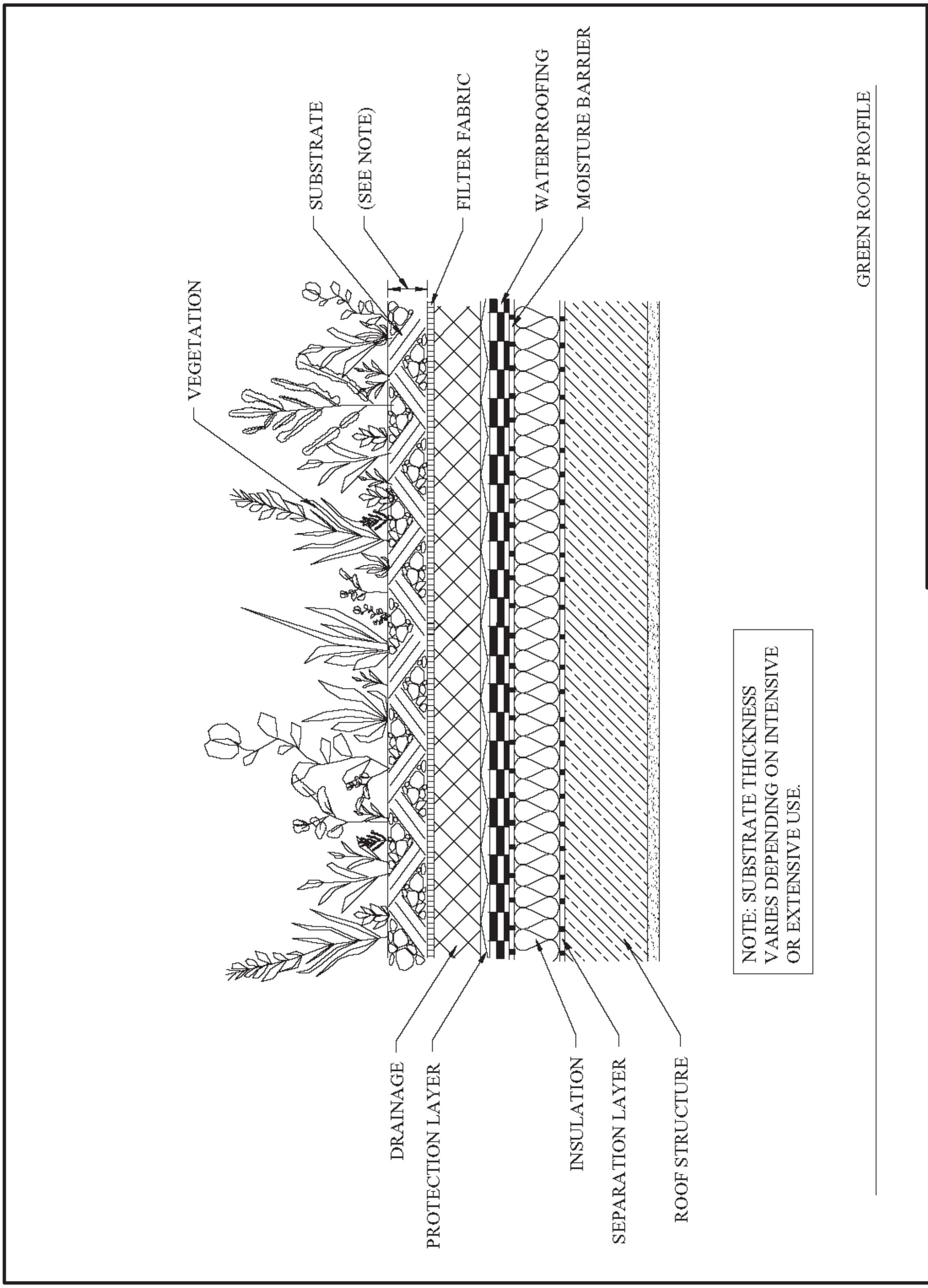

FIGURE 10-2. TYPICAL GREEN ROOF